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Request for grant of a patent

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1. Your reference	JWB/DS/57722	
2. Patent application number *(The Patent Office will fill in this part)*	11 OCT 1999	9924046.7
3. Full name, address and postcode of the or of each applicant *(underline all surnames)*	FAST Technology GmbH Feringastr. 6 85774 Unterfoehring GERMANY	
Patents ADP number *(if you know it)*		7719990001
If the applicant is a corporate body, give the country/state of its incorporation	GERMANY	
4. Title of the invention	TORQUE MEASUREMENT APPARATUS	
5. Name of your agent *(if you have one)*	LLOYD WISE, TREGEAR & CO	
"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	Commonwealth House 1-19 New Oxford Street London WC1A 1LW UNITED KINGDOM	
Patents ADP number *(if you know it)*	117001	

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7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application	Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:* *a) any applicant named in part 3 is not an inventor, or* *b) there is an inventor who is not named as an applicant, or* *c) any named applicant is a corporate body.* *See note (d))*	YES

TORQUE MEASUREMENT APPARATUS

The present invention relates to the measurement of torque generated in a drive shaft. More particularly, it concerns the non-contacting measurement of such torque using magnetised transducers and seeks to compensate for the effects of interfering magnetic fields.

There have been prior proposals to use magnetised transducer elements for torque measurement, the transducer elements being a ring attached to a torqued shaft or the shaft itself. In this connection reference is made to U.S. Patents 5351555, 5465627 and 5520059 and to published PCT Applications WO99/21150 and WO99/21151. In these specifications the ring or shaft is of magnetoelastic material circumferentially magnetised, that is the magnetisation forms a closed loop around the shaft. While such transducer elements are usable in the practice of this invention, other patterns of magnetisation are usable and do not necessarily rely on magnetoelasticity, and other shapes of transducer element may be employed. Transducer elements which use longitudinal magnetisation have been developed and are described in UK Patent Application No. 9919065.4 (published on under the number).

These techniques are based on magnetic principles and therefore can be affected by other interfering magnetic fields, like the earth's magnetic field or fields generated by electric motors for example. In some environments where it is desirable to measure shaft torque, very strong magnetic fields may be present, particularly in the longitudinal axis of the sensing system. A typical application of this nature is the extended axis of an electric motor.

The present invention provides a torque transducer for measuring torque in a rotating shaft of the kind having a transducer region in which a magnetic transducer field is established and at least one non-contacting sensor adjacent the transducer region to develop a torque-dependent signal, wherein in operation the shaft is subject to longitudinal flux generated by means external to the transducer region, characterised by means for sensing and providing a signal dependent on the longitudinal flux, and means responsive to said signal and coupled to said shaft to generate a flux to counteract, and preferably nullify, said longitudinal flux at

the transducer region.

Preferably, the responsive means coupled to the shaft comprises at least one current-carrying coil about the shaft. A magnetic structure may also be provided which has poles spaced along the shaft and a coil is wound about said magnetic structure.

The invention also provides torque transducer for measuring the torque in a rotating shaft which, in operation, has a longitudinal field extending therealong, wherein at least one sensor is placed in non-contacting fashion adjacent a portion of the shaft to sense and provide a signal dependent on a transverse (circumferential) component of flux arising from the longitudinal flux due to the torque in the shaft. In the preferred embodiment, a further non-contacting sensor is mounted to sense the longitudinal flux to provide a reference signal dependent thereon for use in obtaining a value for the torque in the shaft.

According to another aspect, the invention provides a transducer assembly for measuring, preferably in a non-contacting fashion, torque in a rotating shaft, the assembly comprising an erase head for cleaning a zone of the shaft as it rotates, a write head downstream of the erase head in the direction of rotation to write a magnetic track onto the cleaned zone, said track having a predetermined width, a pair of read heads spaced in an axial direction to respond to the magnetic track, said read heads being disposed on, toward or adjacent opposite sides of the track to generate respective signals, and differential means responsive to said respective signals to provide a signal dependent on the position of the track relative to said pair of read heads.

To avoid external fields adversely affecting torque measurements, the sensor can be either protected from therefrom or alternatively utilise the external field flux in the measurement process.

Embodiments of the invention will now be described by way of example and with reference to the accompanying drawings wherein:

Figures 1 to 3 illustrate measurement of shaft torque using circumferential magnetisation;

Figures 4 and 5 illustrate measurement of shaft torque using longitudinal magnetisation;

Figure 6 shows the longitudinal magnetic flux developed in the shaft of a typical electric motor;

Figures 7 and 8a show apparatus for cancelling an interfering magnetic field generated by an electric motor according to a first embodiment of the invention;

Figure 8b is an end view of the shaft shown in Figure 8a;

Figures 9a and 9b show side and end views of a shielded and actively compensated transducer in accordance with a second embodiment of the invention;

Figures 10a and 10b show side and end views, respectively, of apparatus for measuring shaft torque using a magnetic field in the shaft according to a third embodiment of the invention;

Figure 11 shows a deflected magnetic field in the shaft of Figure 10a; and

Figures 12a and 12b show side and end views of an arrangement for measuring shaft torque using magnetic erase, read and write heads adjacent a shaft, according to a fourth embodiment of the invention.

Figures 1 to 3 illustrate detection of shaft torque using the technique of circumferential magnetisation referred to above. Under "no torque" the circumferential field is entirely contained in the shaft 4: there is no fringe field. Under torque, the field 2 is skewed to produce an axial N-S component dependent on torque. The resulting fringe field 6 is detectable by sensor 7 and a measure of torque.

Figures 4 and 5 demonstrate detection of shaft torque using longitudinal magnetisation of the shaft. The longitudinal field 8 lies along the shaft forming a torus of magnetisation which is mainly in a closed toroidal loop. The torus extends around the shaft 4. The surface field all lies in the same direction. There is a small quiescent longitudinal fringe field 10 that leaks from the shaft as seen in Fig. 4. Under torque, the field skews (Fig. 5) and produces a small transverse or circumferential component detectable by sensor 22: the longitudinal component is detectable by sensor 21. The sensors have directivity and have a field directivity.

A typical electric motor (63) is shown in Fig. 6 which produces very large magnetic forces during its operation. Depending on the specific design of the motor components and the assembly some of these magnetic fields can exit the motor assembly (unintentionally or inadvertently) through the metallic axis (drive shaft 61) of the motor.

When trying to measure the mechanical torque generated by an electric motor through its axis by using the methods described above with a transducer assembly 62, the longitudinal magnetic flux present in the drive shaft (60) can generate huge sensor offset signals. These offset signals are modulated by the changes of the mechanical load on the motor axis and the supplied electrical current to the motor. The offset is therefore dynamic and cannot be easily compensated for.

In the embodiment of Figures 7, 8a and 8b, the level of the interfering magnetic field strength is measured in real time, and an active magnetic field cancellation system is assembled and mounted at the sensor host. The shaft is collared at 20 to produce a recess 25 which aids in causing internal longitudinal flux to "leak" external to the shaft and be detectable. The external longitudinal flux is detected by sensors 24 which control a current generating means for coils L1, L2 to counteract the external longitudinal flux. Torque is measured using sensor 23.

Figures 9 and 9b show an arrangement similar to that of Figures 7 and 8, and seeks to back off or nullify the motor leakage flux. It is intended for higher levels of flux. L1 and L2 are energised as before in dependence on the flux sensed at 24. The magnetic shield will produce poles when L3/L4 are energised as L1/L2 are dependent on 24. The poles concentrate the shield flux. The polarity induced is the same as the coils L1 and L2. For a small shaft diameter the magnetic shield L3/L4 structure enables higher ampere turn ratings to be accommodated for large leakage fluxes. L3/L4 and shield on one hand and L1/L2 on the other may be applied separately. The shield arrangement may be advantageous when there are other stronger sources of stray magnetic field in the vicinity of the transducer. For example the shield may protect the transducer from fields of the order of 100 or more Gauss, whilst coils L1 and L2 typically protect against fields of the order of tens of Gauss.

A different approach is adapted in the apparatus of Figs. 10a, 10b and 11. Rather than nullifying the longitudinal flux from motor it is instead used as the transducer flux source in

a longitudinal magnetisation type measurement. Here collared structure again aids in producing a longitudinal (axial) directed external field. The longitudinal sensors 24 measure the longitudinal flux (of whatever value). The transverse sensor(s) 23 measures the circumferential value. The torque calculation is made independent of the actual flux in the shaft by using this as a reference.

The axial component (measured by 24) is used to determine the maximum available field strength to measure mechanical forces at the sensor region. The result of this measurement is used to control the gain of the force sensing magnetic field sensor. The greater the longitudinal magnetic field (60), the higher the gain of the magnetic field measured by the circumferentially arranged magnetic field sensors. Therefore the amplification gain in the signal conditioning electronics for the circumferentially magnetic field sensors need to be reduced in proportion of the increase in the longitudinal magnetic field.

As shown in Fig. 11, the longitudinal field that is travelling through the shaft will be deflected (60a) in relation to the applied mechanical forces on this drive shaft(61). The whole shaft effectively acts as a force sensor. The greater the torque, the larger the circumferential component of the field, measured by sensor 23 and the smaller the axial component measured by sensor 24.

Another technique for torque measurement is illustrated in Fig. 12. As the shaft rotates a circumferential band 16 is cleared by an erase head(s) 12. Following the erase head (downstream), a write-head 13 writes a magnetic track 15 (of any kind) whose critical feature is its width w. The shaft should preferably be rotating at at least 100 rpm when using this technique.

The two read-heads 14a and 14b are critically spaced relative to the width to give no signal when the shaft is barely rotating or known balanced signals that can be nulled. As torque builds in the shaft, the magnetised track 15 is slightly deflected one-way or the other dependent on direction of rotation to produce an unbalance output from the read-heads 14a and 14b that is a measure of torque.

The write-head 13 may preferably modulate the track 15 in some way to provide a signal at each read head that can be separated from noise.

CLAIMS

1 A torque transducer for measuring torque in a rotating shaft of the kind having a transducer region in which a magnetic transducer field is established and at least one non-contacting sensor adjacent the transducer region to develop a torque-dependent signal, wherein in operation the shaft is subject to longitudinal flux generated by means external to the transducer region, characterised by means for sensing and providing a signal dependent on the longitudinal flux, and means responsive to said signal and coupled to said shaft to generate a flux to counteract, and preferably nullify, said longitudinal flux at the transducer region.

2 A torque transducer as claimed in Claim 1 wherein said means coupled to the shaft comprises at least one current-carrying coil about the shaft.

3 A torque transducer as claimed in Claim 2 in which a magnetic structure has poles spaced along the shaft and a coil is wound about said magnetic structure.

4 A torque transducer for measuring the torque in a rotating shaft which, in operation, has a longitudinal field extending therealong, wherein at least one sensor is placed in non-contacting fashion adjacent a portion of the shaft to sense and provide a signal dependent on a transverse (circumferential) component of flux arising from the longitudinal flux due to the torque in the shaft.

5 A torque transducer as claimed in Claim 4 in which a further non-contacting sensor is mounted to sense the longitudinal flux to provide a reference signal dependent thereon for use in obtaining a value for the torque in the shaft.

6 A transducer assembly for measuring, preferably in a non-contacting fashion, torque in a rotating shaft, the assembly comprising an erase head for cleaning a zone of the shaft as it rotates, a write head downstream of the erase head in the direction of rotation to write a magnetic track onto the cleaned zone, said track having a predetermined width, a pair of read heads spaced in an axial direction to respond to the magnetic track, said read heads being disposed on, toward or adjacent opposite sides of the track to generate respective signals, and differential means responsive to said respective signals to provide a signal dependent on the position of the track relative to said pair of read heads.

circumferentially magnetised

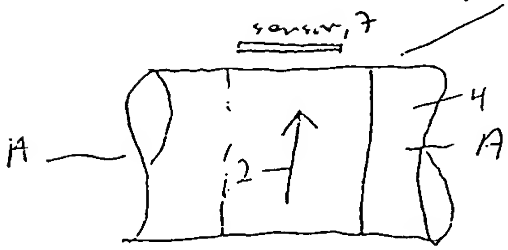


Fig.1

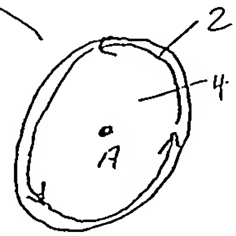


Fig.2

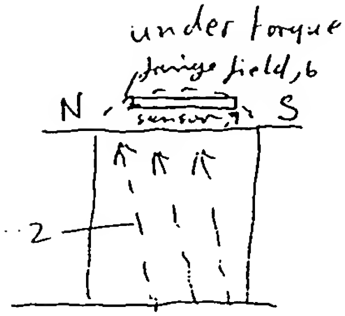


Fig.3

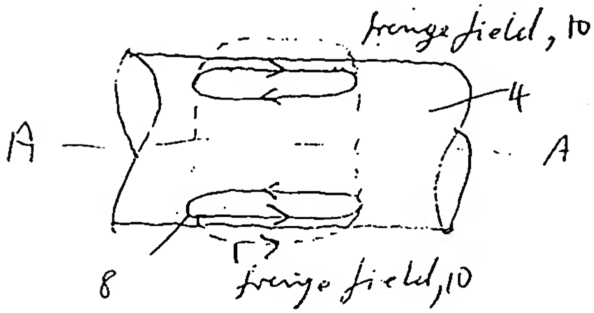


Fig. 4

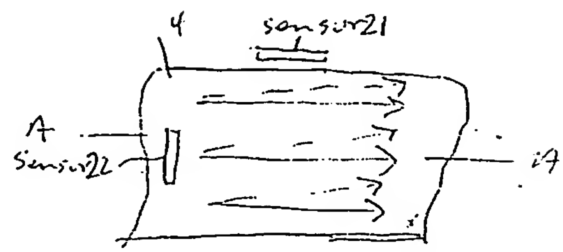


Fig. 5

Fig.6

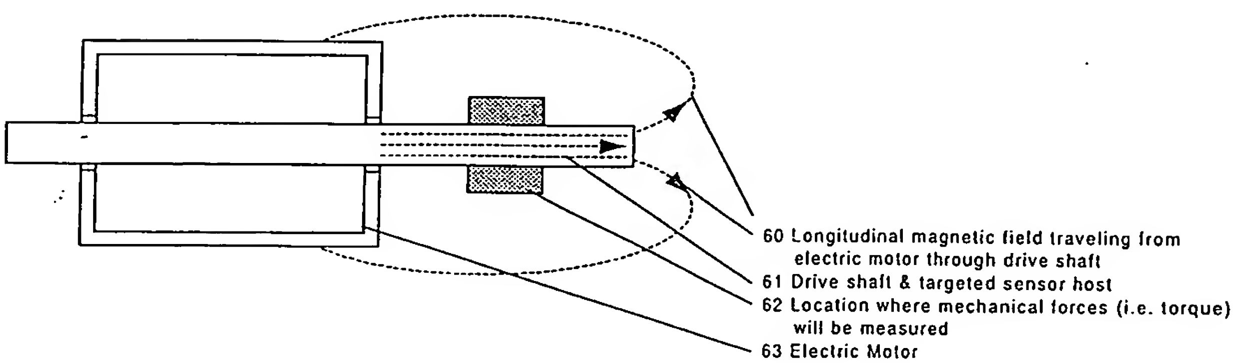


Fig. 7

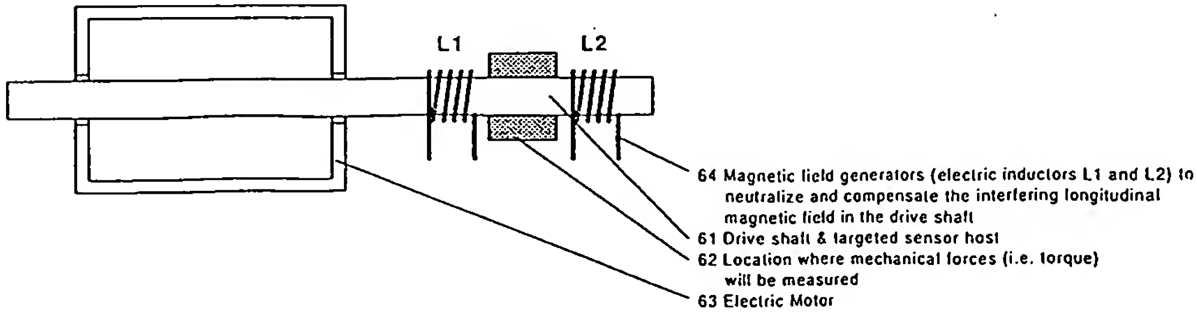
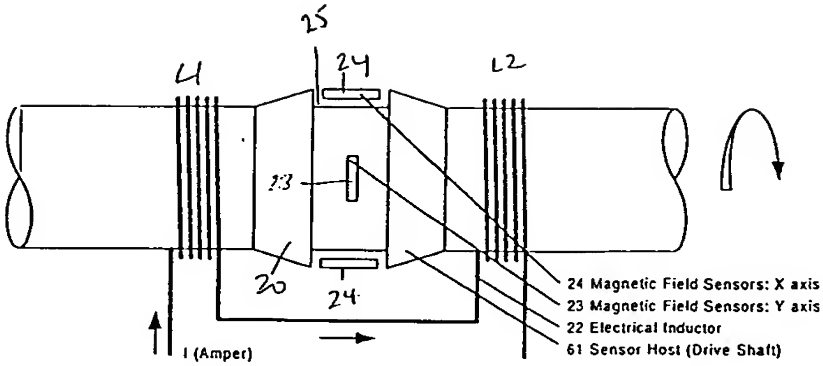


Fig. 8a



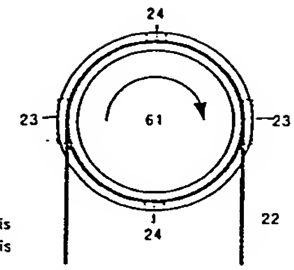
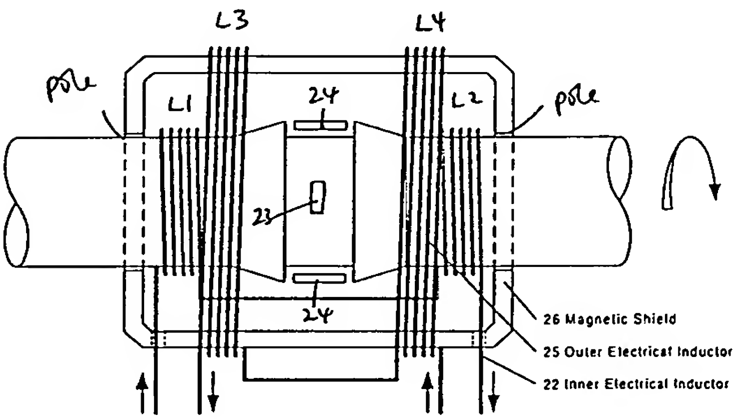


Fig 8b

Fig 9a



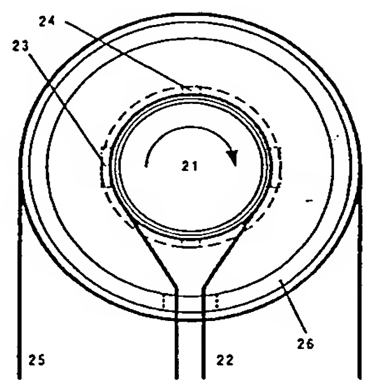
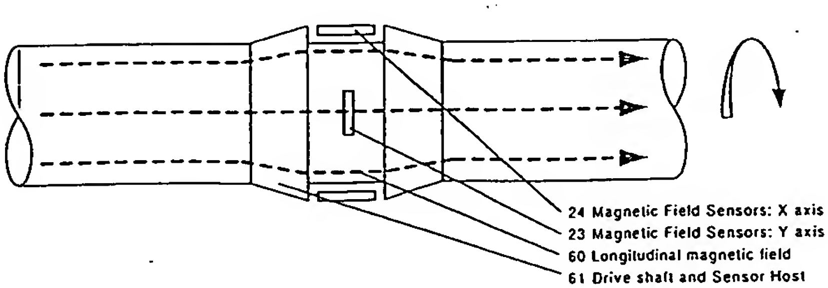


Fig. 9b.

Fig 10.a



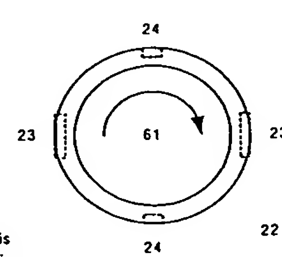


Fig 10b

Fig 11.

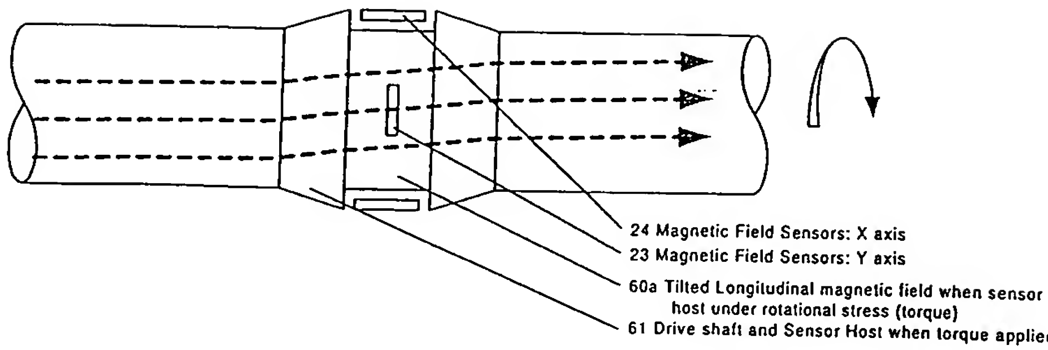
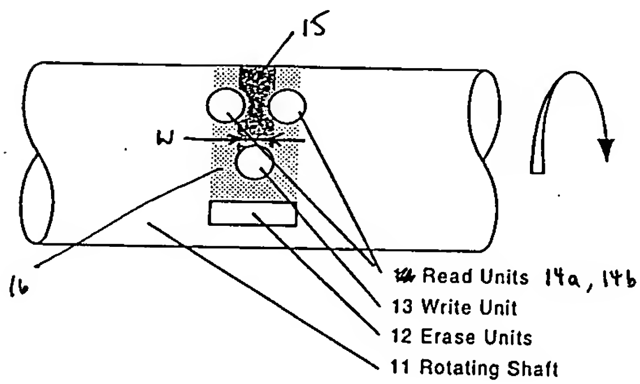


Fig 12



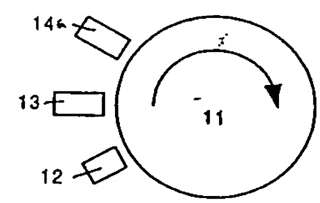


Fig 12 b